EFFECTS OF *NYMPHAEA CAERULEA* ON WASTEWATER QUALITY FROM PALM OIL PRODUCTION

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ABSTRACT

Palm oil industry is the most important agro-industry in Malaysia, but its by-product–palm oil mill effluent (POME), posed a great threat to water environment. Although the palm oil industry has applied biological treatment for POME, it still faces challenge of balancing the environmental protection, its economic viability and sustainable development. This experiment was carried out to examine the feasibility of POME treatment by using *Nymphaea Caerulea*. The sample was obtained from LCSB Oil Palm Plantation in Lepar Hilir and analysis would be conducted at University Malaysia Pahang in laboratory scale. The aquatic plant was collected from Semuji Agro Resort. The objectives of this experiment are to study the feasibility of aquatic plants in POME treatment for POME at stage 7 and to investigate treatment efficiency by using optimal design condition whereby emphasis is placed on waste water circulation. The presence of circulation in this experiment is to enhance the kinetic process, as compared to control. The sample is tested on day 1, day 3 and day 5. The parameters to be evaluated include BOD, COD, pH, TSS and Oil and Grease. From overall experiment, the highest percentage removal of BOD is 76%, COD is 62%, TSS is 56%, Oil and Grease is 84.7%. The specimen of plant can reduce the pH level. It is shown that in the presence of *Nymphaea Caerulea* that is supplemented with circulation can improve the water quality with five days of retention time compared to control.

ABSTRAK

Industri minyak sawit merupakan agro-industri terpenting di Malaysia, tetapi produk sampingannya iaitu sisa minyak sawit (POME) menjadi ancaman yang besar kepada persekitaran air. Walaupuan industri sawit telah melaksanakan rawatan biological terhadap POME, ianya masih lagi menghadapi cabaran untuk mengimbang penjagaan persekitaran, kelayakan ekonomi dan pembangunan berterusan Ujikaji ini adalah bertujuan untuk memeriksa kebolehlaksanaan *Nymphaea Caerulea* dalam merawat POME. Sampel diperolehi dari LCSB Oil Palm Plantation in Lepar Hilir dan dianalisis di Universiti Malaysia Pahang. Tumbuhan akuatik ini didapati dari Semuji Agro Resort. Objektif ujikaji ini adalah untuk mengetahui kebolehlaksaan Nymphaea Caerulea dalam merawat POME pada tahap 7 dan untuk menyiasat kecekapan rawatan menggunakan keadaan rekabentuk optimum dimana kitaran air sisa ditekankan. Dengan adanya kitaran dalam ujikaji ini adalah bertujuan untuk meningkatkan proses kinatik jika dibandingkan dengan sistem kawalan. Sampel diuji pada hari pertama, ke-3 dan ke-5. Parameter yang dinilai ialah BOD, COD, pH, TSS dan Minyak dan Gris. Daripada keseluruhan ujikaji, peratusan penyikiran tertinggi untuk BOD ialah 76%, COD ialah 62%, TSS ialah 56%, dan Minyak dan Gris ialah 84.7%. Selain itu, specimen tumbuhan boleh menurunkan paras pH. Ini menunjukkan bahawa dengan kehadiran tumbuhan akuatik bersama dengan kitaran boleh meningkatkan lagi kualiti air dalam tempoh 5 hari jika dibandingkan dengan sistem kawalan.

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LIST OF ABBREVIATIONS

BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
CPO	-	Crude Palm Oil
DO	-	Dissolved Oxygen
EFB	-	Empty Fruit Bunch
EPA	-	Environmental Protection Agency
EQA	-	Environmental Quality Act 1974
FFB	-	Fresh Fruit Bunch
H_2SO_4	-	Sulfuric Acid
MPOB	-	Malaysian Palm oil Board
MPOC	-	Malaysian Palm Oil Council
O&G	-	Oil and Grease
POME	-	Palm Oil Mill Effluent
TKN	-	Total Kjeldahl Nitrogen
TSS	-	Total Suspended Solids
SS	-	Suspended Solids

LIST OF SYMBOLS

%	-	percent
°C	-	degree of Celsius
cm	-	centimeter
L	-	Liter
m	-	meter
mg/L	-	milligram per Liter
mL	-	milliliter
mm	-	milimeter

CHAPTER 1

INTRODUCTION

1.1 Introduction of Palm oil

Palm oil has played a positive role in the world oils and fats supply and demand equation largely due to its techno-economic advantages and versatility as well as some of the developments in the world in relation to security of supply, health and environment. Palm oil industry is the most important agro-industry in Malaysia, but its by-product–palm oil mill effluent (POME), posed a great threat to water environment. In the past decades, several treatment and disposal methods have been proposed and investigated to solve this problem (Zhang, 2007).

1.2 Research background

Malaysia currently accounts for 41 % of world palm oil production and 47% of world exports, and therefore also for 11% and 25% of the world's total production and exports of oils and fats. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats in general (MPOC, 2009). In general, the palm oil milling process can be categorized into a dry and a wet (standard) process. The wet process of palm oil milling is the most common and typical way of extracting palm oil, especially in Malaysia (T.Y. Wu et al., 2008).

Palm oil processing is carried out in palm oil mills where oil is extracted from a palm oil fresh fruit bunch (FFB). A Significant quantity of water needed in the palm oil mill extraction. In daily life, palm oil is used mainly in producing cooking oil, margarine, soap, detergent, cosmetics and else. Palm oil mill effluent (POME) is a waste produced from the palm oil processing plants. POME is a thick brownish color and discharged at a temperature between 80ºC - 90ºC. It is fairly acidic with pH ranging from 4-5. POME is an organic wastewater from palm oil industry with high biochemical oxygen demand (BOD) which is about one hundred times more than that of sewage. Besides that, POME also contains high chemical oxygen demand (COD) and suspended solid. This oily waste is produced in large volumes and contributes major problem to the palm oil processing mill's waste stream. Thus it has to be treated efficiently to avoid environmental hazard. If such wastewater is discharged to the environment without a proper treatment, it can pollute the watercourse, river and as well as receiving bodies. Most of the public complaints regarding water pollution were directed at the palm oil industry and the natural rubber processing industry during the last decade (A. R. Khalid, W.A Wan Mustafa, 1992). To minimize the impact of this problem towards the environment, a new method is required in POME treatment with low cost, new enhancement of efficiency and more profitable to palm oil industry. In addition, the role of aquatic plant can reduce the contaminant in POME in order to meet the requirement of Department of the Environment (DOE) discharge limits.

1.3 Problem Statement

Nowadays, water pollution is a major problem in Malaysia. Pollutants such as herbicides, pesticides, fertilizers, and hazardous chemicals can make their way into our water supply. When our water supply is contaminated, it is a threat to human, animal, and plant health unless it goes through a costly purification procedure. Pollutants can contaminate our drinking water sources, reduce oxygen levels which can kill fish and other wildlife, accumulate in the tissue of fish we catch and eat from the lakes, and reduce the beauty of the water.

In Malaysia, there are two main sources of water pollution which are domestic sewage and industrial waste. From the previous research, industrial waste has higher pollutant than domestic sewage. In industrial wastewater treatment, the most common and efficient system applied in industry by the palm industry are ponding system, the open tank digester, close tank digester, thermophilic anaerobic contact process and extanded aeration. Although the palm oil industry has applied biological treatment for POME, it still faces challenge of balancing the environmental protection, its economic viability and sustainable development (Ahmad et al, 2003).

Several studies and research have been done by the government, private sector and also educational institute to find the most effective techniques to treat the POME. Generally, Malaysia rarely used aquatic plants in industrial waste water treatment. In this research, we will introduce a new method for POME treatment by using aquatic plants. This method is required in order to give a better solution in managing this waste which is economic and environmental friendly. Besides that, the aim of this research is also to fulfill the requirements of Department of Environmental (DOE) discharge limits.

1.4 Objectives

- To study the feasibility of plant (Nymphaea Caerulea) in POME treatment for POME at stage 7.
- To investigate treatment efficiency by using optimal design condition whereby emphasis is placed on waste water circulation.

1.5 Scope of the research

- The sample of palm oil mill effluent is obtained from LCSB Oil Palm Plantation in Lepar Hilir and analysis will be conducted at University Malaysia Pahang.

- *Nymphaea Caerulea* will be examined in order to observe its effectiveness on palm oil mill effluent (POME) treatment. This plant is collected from Semuji Agro Resort.
- In order to complete this research, the parameters that must be measured are BOD, COD, pH, total solids, suspended solids, and oil and grease.
- POME at stage 7 will be used in this research because of the concentration for each stage is different. POME at stage 7 has low concentration compared to other stages.

1.6 Rational and significance

POME can be classified as a major problem in water pollution in Malaysia. In this research, POME treatment by using aquatic plant which is *Nymphaea Caerulea* gives us more advantages in order to achieve the requirements of Department of Environmental (DOE) discharge limits. The rational and significance of this research include:

- By using this aquatic plant, it can save our environment by reducing water pollution.
- *Nymphaea Caerulea* growth in the lake and exist in abundance.
- The method using this aquatic plant is low in cost. Thus, it is very economical and effective.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Palm oil is an edible plant oil derived from the fruit and kernels (seeds) of the oil palm *Elaeis guineensis*. Palm oil is naturally reddish because it contains a high amount of beta-carotene (though boiling it destroys the carotenoids and renders the oil colourless). Palm oil is one of the few vegetable oils relatively high in saturated fats (like coconut oil) and thus semi-solid at room temperature. Palm oil production is a basic source of income for many of the world's rural poor in South East Asia, Central and West Africa, and Central America. In 2003, Malaysia produced 14 million tons of palm oil from more than 38,000 square kilometers of land, making it the largest exporter of palm oil in the world. Palm oil processing is carried out in palm oil mills where oil is extracted from a palm oil fruit bunch. In daily life, palm oil is used mainly in produce cooking oil, margarine, soap, detergent, cosmetics and else. The extraction process for crude palm oil (CPO) starts from the local palm oil mills throughout Malaysia. The mills processes FFB received from the oil palm plantations into CPO and other by-products. A schematic process flow of palm oil milling for the extraction of crude palm oil and sources of waste generation is shown in Fig. 2.1. Palm oil mills typically generate large quantities of extremely oily organic contented liquid (Industrial Processes and The Environment, 1999).

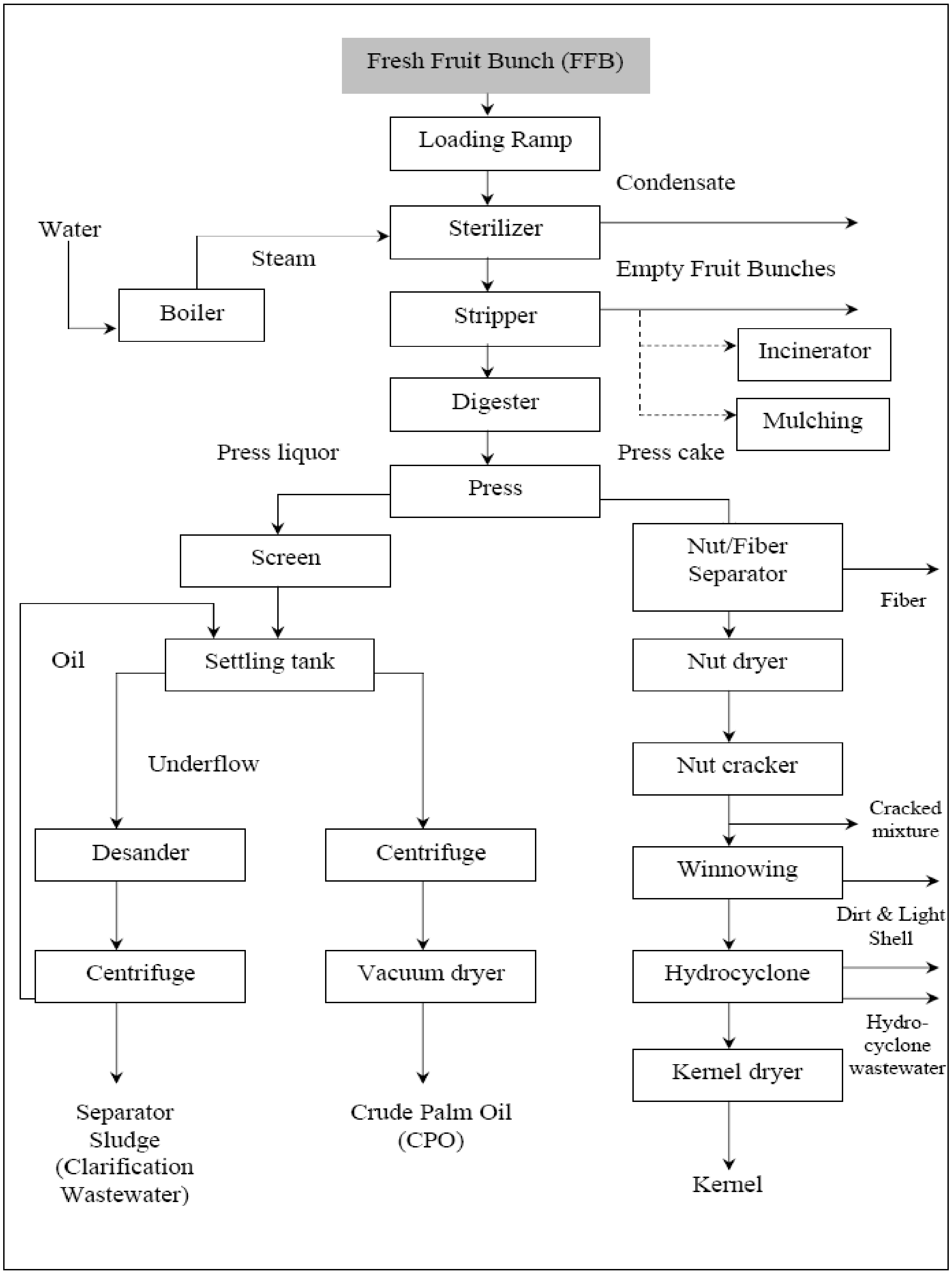

Figure 2.1 A schematic process flow of palm oil milling for the extraction of crude palm oil and sources of waste generation

2.2 PALM OIL MILL EFFLUENT (POME)

Palm oil mill effluent is a waste produced from the palm oil processing plants. This oily waste is produced in large volumes and contributes major problem to the palm oil processing mill's waste stream. Thus it has to be treated efficiently to avoid environmental hazard. Besides, the process to extract the oil requires significantly large quantities of water for steam sterilizing the palm bunches and clarifying the extracted oil. It is estimated that for 1 tonne of crude palm oil produced 5-7.5 tonnes of water are required, and more than 50% of the water will end up as palm oil mill effluent (POME) (Ahmad et al.,2003). Thus, while enjoying a most profitable commodity, the adverse environmental impact from the palm oil industry cannot be ignored.

Raw POME is a colloidal suspension which is 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids originating in the mixing of sterilizer condensate, separator sludge and hydrocyclone wastewater (Ahmad et al., 2003; Borja and Bark, 1996; Khalid and Wan Mustafa, 1992; Hameed Bassim, 2003). If the untreated effluent is discharged into watersources, it is certain to cause considerable environmental problems due to its high biochemical oxygen demand, BOD (25,000 mg/l), chemical oxygen demand, COD (50,000 mg/l), total solids (40,500mg/l), suspended solid (18,000mg/l) and 4,000 mg/l of oil and grease.

Table 2.1 Characteristics of POME and its respective standard discharged limit by the Malaysian Department of the Environment.

Parameter	Concentration, mg/L	Standard limit, mg/L
pH	4.7	5-9
Oil and grease	4,000	50
BOD	25,000	100
COD	50,000	--
Total solids	40,500	--
Suspended solids	18,000	400
Total nitrogen	750	150

However it contains appreciable amounts of N, P, K, Mg and Ca which are the vital nutrient elements for plant growth (Industrial Processes & The Environment, 1999).

Table 2.2 Characteristics of combined palm oil mill effluent (POME) (Industrial Processes& The Environment, 1990)

Parameters	Mean	Range	Metals & Other Constituents	Mean
pH	4.2	3.4-5.2	Phosphorus	180
Oil & Grease	6,000	150-18,000	Potassium	2,270
BOD; 3-day, 30°C	25,000	10,000-44,000	Magnesium	615
COD	50,000	16, 000-100,000	Boron	7.6
Suspended Solid	40,500	11,500-79,000	Iron	47
Dissolved Solids	18,000	5,000-54,000	Manganese	2.0
Ammonical Nitrogen	35	4-80	Copper	0.9
Total Nitrogen	750	80-1,400	Zinc	2.3
			Calcium	440

*All units are in mg/l except for pH

Table 2.3 Environment Quality Act 1974

THIRD SCHEDULE

ENVIRONMENTAL QUALITY ACT 1974

ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS) REGULATIONS 1979

(REGULATIONS 8(1), 8(2), 8(3)

PARAMETER LIMITS OF EFFLUENTS OF STANDARDS A AND B

Parameter		Unit	Standard	
			A	B
(i)	Temperature	°C	40	40
(ii)	pH value	-	6.0 - 9.0	5.5 - 9.0
(iii)	BOD at 20°C	mg/ l	20	50
(iv)	COD	mg/ l	50	100
(v)	Suspended Solids	mg/ l	50	100
(vi)	Mercury	mg/ l	0.005	0.05
(vii)	Cadmium	mg/ l	0.01	0.02
(viii)	Chromium, Hexavalent	mg/ l	0.05	0.05
(ix)	Arsenic	mg/ l	0.05	0.10
(x)	Cyanide	mg/ l	0.05	0.10
(xi)	Lead	mg/ l	0.10	0.5
(xii)	Chromium Trivalent	mg/ l	0.20	1.0
(xiii)	Copper	mg/ l	0.20	1.0
(xiv)	Manganese	mg/ l	0.20	1.0
(xv)	Nickel	mg/ l	0.20	1.0
(xvi)	Tin	mg/ l	0.20	1.0
(xvii)	Zinc	mg/ l	2.0	2.0
(xviii)	Boron	mg/ l	1.0	4.0
(xix)	Iron (Fe)	mg/ l	1.0	5.0
(xx)	Phenol	mg/ l	0.001	1.0
(xxi)	Free Chlorine	mg/ l	1.0	2.0
(xxii)	Sulphide	mg/ l	0.50	0.50
(xxiii)	Oil and Grease	mg/ l	Not Detectable	10.0

According to POME characteristic and standard discharge limit in EQA 1974, the palm oil industry faces the challenge of balancing the environmental protection, its economic viability and sustainable development.

In terms of biochemical oxygen demand (BOD) which amounts to 25000 mg/l, it is highly polluting. It is 100 times more polluting than the domestic sewage. Besides that, the suspended solid in the POME are mainly cellulosic material from the fruit. When the biodegradable organics are discharged to stream containing dissolved oxygen, microorganisms begin the metabolic processes that convert the organics along with the dissolve oxygen into new cells and oxidized waste products. The quantity of oxygen required for this conversion is the biochemical oxygen demand.

Because of the pressing problems of the disposal of palm oil mill wastes, the environmental quality regulation for CPO mills was formulated. The regulation was cited as the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulation, 1977. The mills were required to reduce the effluent components, using BOD as a critical parameter, from 20,000 m~ L -1 to 5,000 mg L -1 in 1978, and to 500 mg L -1 by 1981. These BOD limits were further reduced to 250 m~z L -1 in 1982, 100 mg L -1 in 1983 and 50 mg L -'T in 1986 (Khalid and Wan Mustafa, 2003). The effluents have been discharged into water courses causing serious pollution, killing fish, prawns and crabs on which some fishermen depend. They leave unsightly sludge and stench on river banks and ditches. There is an urgent need to find a way to preserve the environment while keeping the economy growth.

2.3 Treatments of POME

Khalid and Wan Mustafa (2003) said that, since 1974, a considerable amount of research has been carried out to establish reasonably acceptable methods for treatment and disposal of palm oil mill effluents. Various treatment technologies have been developed with local expertise and a number of mills have installed treatment plants since that time. The three most common and efficient treatment systems adopted by the palm oil industry are the ponding system, the open tank digester and extended aeration system, and the closed anaerobic digester and land application system. The choice of which system is used depends very much on the individual mills, company policy, location and availability of suitable land.

Membrane separation technology has been widely used in water and wastewater treatment and has been applied in various types of industry (Zhang et al., 2008). Besides that, a POME treatment system based on membrane technology shows high potential for eliminating the environmental problem, and this alternatives treatment system offers water recycling (Ahmad et al., 2003)

Anaerobic digestion is usually the basic biological treatment process for high organic strength wastewaters, since it results in limited production of stabilized sludge compared to the conventional aerobic treatment. Anaerobic digestion of organic material under methanogenic conditions, is a complex process (Aggelis et al., 2001). Besides that, the disadvantage of anaerobic digesters is that additional treatment is necessary to polish and lower the pollution load (Alvares et al., 2008)

Biological treatment of green olive debittering wastewater was investigated using aerobic and anaerobic systems based on combined and separate reactors. The results showed that aerobic treatment was found to be more efficient than the anaerobic, whereas combined anaerobic–aerobic treatment yielded less aerobic sludge (Aggelis et al., 2001).

2.4 Parameters

2.4.1 Chemical oxygen demand (COD)

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes The dichromate reflux method is preferred over procedures using other oxidants (e.g. potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is 95-100% of the theoretical value.

2.4.2 Biochemical oxygen demand (BOD)

Biochemical oxygen demand (BOD) test measures the ability of naturally occurring microorganisms to digest organic matter, usually in 5 days incubation at 20°C by analyzing the depletion of oxygen. BOD is the most commonly used parameter for determining the oxygen demand on the receiving water of a municipal or industrial discharge. BOD can also be used to evaluate the efficiency of treatment processes, and is an indirect measure of biodegradable organic compounds in water.

2.4.3 pH

pH is the measure of acidity or alkalinity of water. Measured on a scale of 0-14, solutions with a pH of less than 7.0 are acids while solutions with a pH of greater than 7.0 are bases. In very simple terms bases are used to neutralize acids, while acids are used to neutralize caustics The pH scale commonly in use ranges from 0 to 14. In the process of waste water, the pH is very important to determine the proper chemical processing and corrosion control.

2.4.5 Total suspended solid (TSS)

Total suspended solid is the quantity of solid particles contained in wastewater. Suspended solids, where such material is likely to be organic and/or biological in nature, are an important parameter of wastewater. The suspended solids parameter is used to measure the quality of wastewater influent, to monitor several treatment processes, and to measure the quality of the effluent. Environmental Protection Agency (EPA) has set a maximum suspended solids standard of 30 mg/L for most treated wastewater discharges. Other suspended material may result from human use of the water. Domestic wastewater usually contains large quantities of suspended solids that are mostly organic in nature. Industrial wastewater may result in a wide variety of suspended impurities of either organic or inorganic nature. Immiscible liquids such as oils and greases are often constituents of wastewater.

2.4.6 Oil and grease

Oil and grease content of domestic and certain industrial wastes and of sludges is an important consideration in the handling and treatment of the material for ultimate disposal. Oil and grease are singled out for special attention because of their poor solubility in water and their tendency to separate from the aqueous phase. Although this characteristic is advantageous in facilitating the separation of oil and grease by use of floatation devices, it does complicate the transportation of wastes through pipelines, their destruction in the biological treatment unit, and their disposal into receiving waters (Abid Baig et al., 2003)

2.5 Aquatic plants

The aquatic plants within a lake are often grouped by managers into three plant communities, or assemblages of species, according to their growth form and depth range within a lake. In practice, there are no hard divisions between plant communities. Some plants are adapted to growing in a wide variety of conditions and may be found associated with more than one plant community, while other plants are very specific to a Aquatic plants — also called hydrophytic plants or hydrophytes — are plants that have adapted to living in or on aquatic environments. Because living on or under water surface requires numerous special adaptations, aquatic plants can only grow in water or permanently saturated soil narrow range of environmental conditions and occur in only one plant community.T he three plant communities—emergent, floating-leaf and submergent—are named according to the predominant plant form found in the community. They typically form concentric rings within our lakes. However, under certain conditions one or more plant communities may be absent from a portion of a lake.

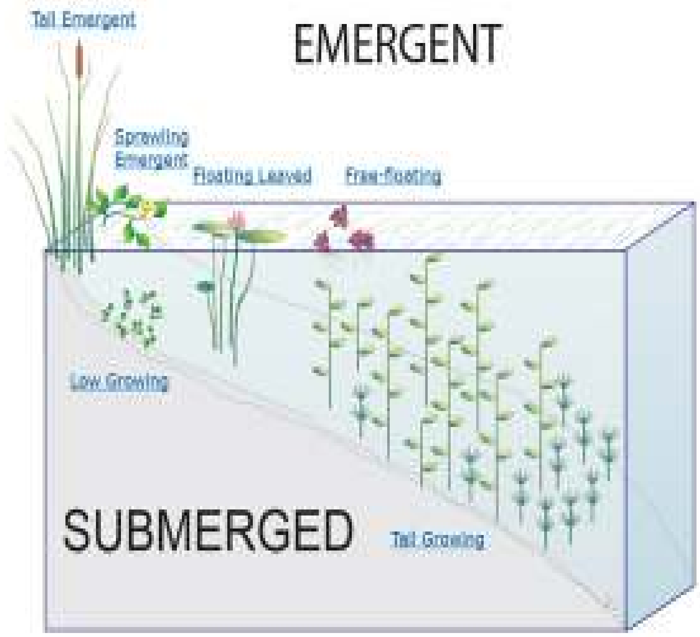

Figure 2.2 Aquatic plants communities

2.5.1 The Emergent Plant

The emergent plant community extends from the water's edge to a depth of 2–4 feet. This area typically receives high nutrient inputs from runoff from the land. It supports predominantly emergent plants that have leaves and flowers extending above the water surface and a dense network of roots. These roots anchor plants (and soil) in the area right along the shoreline that typically is most exposed to the erosive power of waves and ice action. Emersed (aerial) leaves are essentially like typical leaves of herbaceous angiosperms that inhabit full-sun environments. Such leaves are emergent from the water and, consequently, have a waxy cuticle on both surfaces. Many are also amphistomatic (stomates on both surfaces and in nearly equal densities) and have well-developed leaf mesophyll, to take advantage of the abundant light.